On the Origin of Harmful Algal Bloom Species in Pacific Coast Estuaries: Perspectives from the Olympic Region Harmful Algal Bloom (ORHAB) Project

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Abstract
Ecology is a partner in the National Oceanographic and Atmospheric Administration (NOAA)-sponsored Olympic Region Harmful Algal Bloom (ORHAB) project. ORHAB is a joint effort including federal, state, tribal, private, and academic partners to understand the processes that cause harmful algal blooms (HABs) both offshore and within our coastal estuaries. Ecology's role within this project is to understand the HAB connection between coastal estuaries and adjacent coastal waters: to identify whether the coastal areas are acting in unison or independently. Our goal is to understand whether HAB events within Willapa Bay are imported from the coastal ocean waters under specific conditions or originate from endemic populations within the bay. This is important because different monitoring and management strategies would be indicated.

To evaluate this, we are comparing hydrographic, nutrient and phytoplankton data from Bay Center in Willapa Bay and numerous locations from the outer coast. Our preliminary data from 2002 have shown a connection between higher salinity, colder water at the Bay Center mooring site and increased numbers of diatoms at the same location, although dinoflagelletes do not show this pattern. We are exploring the possibility that an influx of ocean water into the estuary is the cause of some, but probably not all, toxic algal blooms.

Ecology is a partner in the NOAA-sponsored Olympic Region Harmful Algal Bloom (ORHAB) project. ORHAB is a joint effort including federal, state, tribal, private, and academic partners to understand the processes associated with harmful algal blooms (HABs) both offshore and within our coastal estuaries. Partners include: Northwest Fisheries Science Center (NMFS, NOAA), National Centers for Coastal Ocean Science (NOAA), Washington State Departments of Ecology, Fish and Wildlife, and Health, Fisheries and Oceans Canada, Olympic Coast National Marine Sanctuary, University of Washington School of Oceanography and Olympic Natural Resource Center, Pacific Shellfish Institute, Makah Tribe, Northwest Indian College, Quinault Indian Nation, Saigene Corporation and Battelle Marine Science Laboratory.

Ecology's role within this project is to understand the dynamics of harmful algal blooms in the coastal estuaries as compared to the adjacent coastal waters. Are these areas acting in unison or independently? Ecology's goal is to understand whether HAB events within Willapa Bay are imported from the coastal ocean waters under specific conditions or whether they originate from endemic populations within the bay. This is important because different monitoring and management strategies would be indicated depending on the mechanism causing the phytoplankton bloom.

To evaluate this, we are comparing hydrographic, nutrient and phytoplankton data from Bay Center in the Willapa Bay estuary and numerous locations from the outer coast. Though sites were sampled along the entire Washington coast, this portion of study analysis focused on the data from three locations in the south: Bay Center within Willapa Bay and Long Beach and Twin Harbors on the adjacent open coast (Figure 1). Long Beach and Twin Harbors represent conditions along the coast closest to the mouth of Willapa Bay, as they are located just to the south and north of the bay respectively.

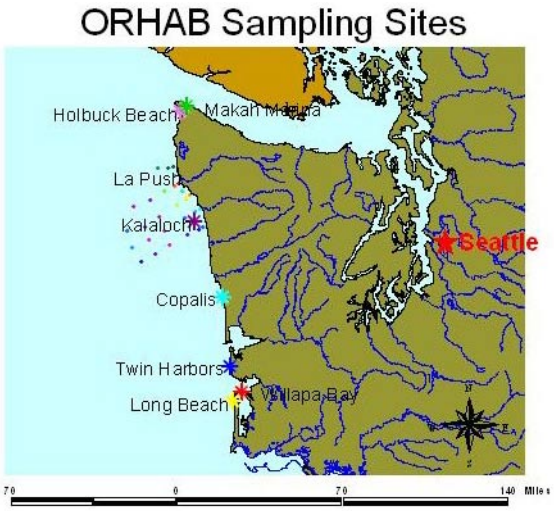

Figure 1. Map of ORHAB monitoring sites.

Data were collected at the United States Coast Guard Navigation Aid near Bay Center within Willapa Bay using a SeaBird Electronics SBE16Seacat (CTD) and WETlabs WETstar fluorometer. Temperature, conductivity and fluorescence were recorded internally every 15 minutes, and the data was downloaded monthly. Secured to an I-beam, the CTD package was able to float up and down with the tide always sampling 1 meter below the surface. In addition, at the higher high tide of the day, an ISCO autosampler collected a 1-L whole water sample for cell count analysis of phytoplankton species. Samples were taken for nutrient and domoic acid toxin analyses every two weeks. Coastal temperature and salinity data from Long Beach and Twin Harbors was collected concurrently with samples for phytoplankton species analysis and toxicity approximately twice a week.

Coastal monitoring sites near Willapa Bay show similar physical data trends at the estuary. In general, temperature and salinity within the bay closely mimic the patterns of temperature and salinity at the coastal monitoring sites (Figure 2). Finer scale resolution from the Bay Center mooring time-series shows strong tidal influence on daily temperature and salinity (Figure 3). Influxes of upwelled ocean water can be seen in Willapa Bay as sharp decreases in temperature and increases in salinity (Figure 4). Salinity is most likely to rise above 29 psu in the estuary when deep water is upwelled off the coast and carried into the bay by the tides. It is important to note, that the salinity in September and October, when coastal upwelling is prevalent, stays above 29 psu almost entirely. Previous work has shown that *Pseudo-nitzschia* cell numbers in Willapa Bay increase when salinity levels rise above 29 psu (Sayce and Horner 1996; Newton and Horner submitted).

Pseudo-nitzschia spp. blooms occur with the influx of ocean waters, but not all ocean influxes influence *Pseudo-nitzschia* (Figure 4). Our data from 2002 have shown a connection between higher salinity and colder water at the Bay Center mooring site and increased numbers of diatoms at the same location. While pennate diatoms bloomed multiple times throughout the summer and fall, only one bloom was primarily composed of *Pseudo-nitzschia* species—the phytoplankton responsible for the production of domoic acid and Amnesic Shellfish Poisoning (ASP). This bloom that occurred in October was due almost entirely to *Pseudo-nitzschia*, while the larger bloom in July was predominantly *Asterionella* species. A sharp rise in nitrate within Willapa Bay was followed by rise in *Pseudo-nitzschia* spp in October 2002 (Figure 5), also indicating a likely oceanic intrusion of recently upwelled water. Our previous research established that phytoplankton growth is limited by nitrogen. The sharp rise in nitrate was not accompanied by increases in the other nitrogen-containing nutrients.

Data from the HAB event in the fall of 2002 provide the opportunity to compare differences in HAB dynamics between the coast and estuary. All three locations in south Washington, Long Beach, Willapa Bay and Twin Harbors had *Pseudo-nitzschia* blooms of proportionate intensity (Figure 6, solid lines) while the levels of domoic acid in seawater and bivalve shellfish (Figure 6, symbols) was not proportionate. The quantity of domoic acid in the water column was nearly 4 times as high at the coastal monitoring stations (3349 ng/L at Twin Harbors and 3606 ng/L at Long Beach) than in Willapa Bay (918 ng/L). While razor clams quickly rose above the 20 ppm action level for harvest closures at the coastal monitoring sites, no sign of toxicity was seen in mussels from the bay. The fact that domoic acid is found in Willapa Bay seawater poses a health risk. The lack of domoic acid in Willapa Bay shellfish when present in seawater needs further investigation.

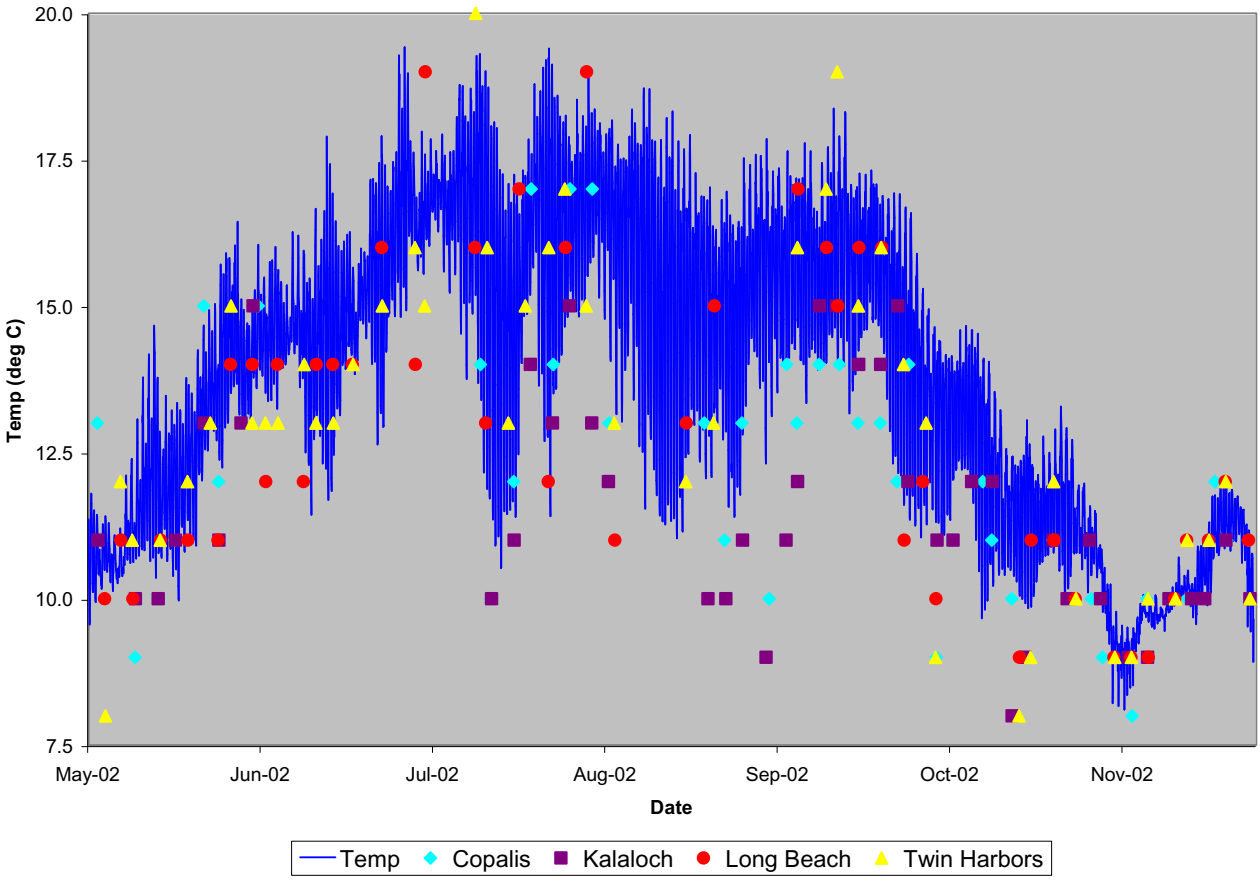

Figure 2. Temperature time-series at Bay Center, Willapa Bay from May 2002 to November 2002 with overlay of temperature data from coastal monitoring sites at Long Beach, Twin Harbors, Copalis, and Kalaloch.

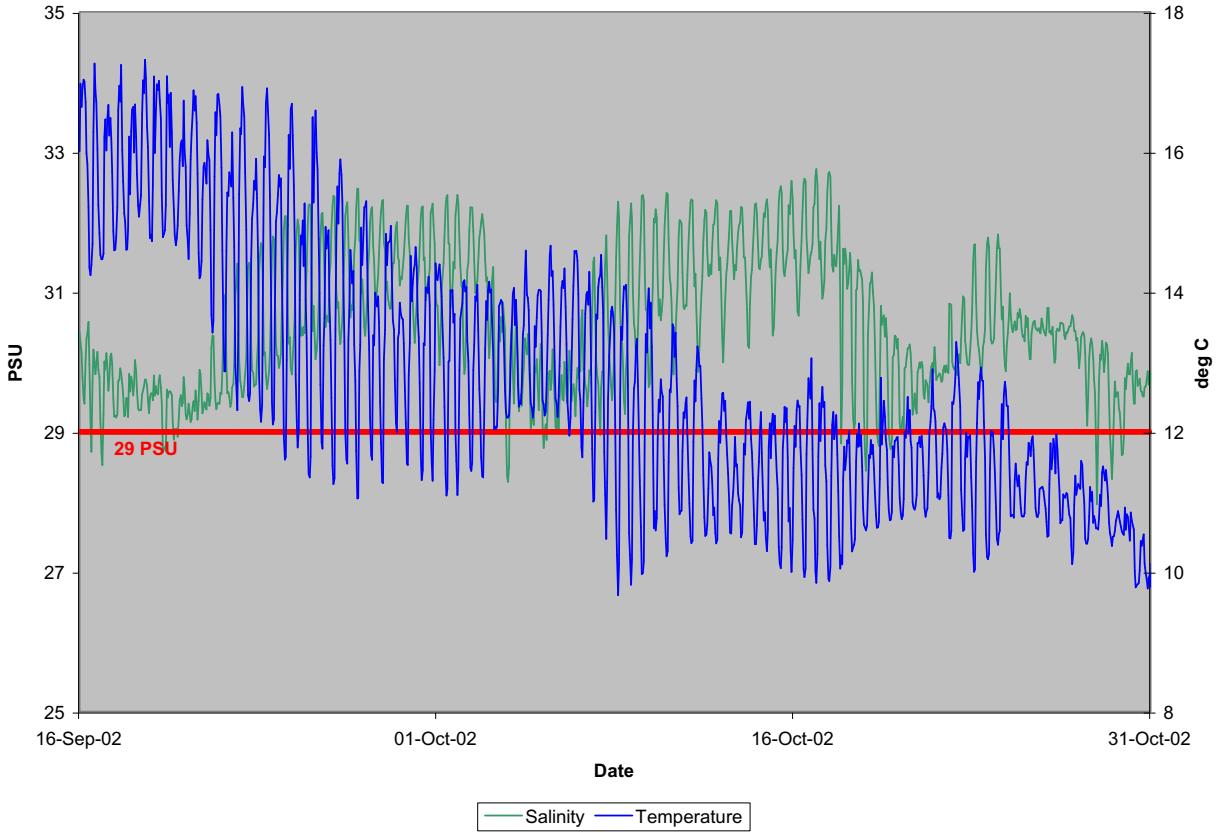

Figure 3. Six-week time-series of temperature and salinity within Willapa Bay at Bay Center mooring, Sept-Oct 2002.

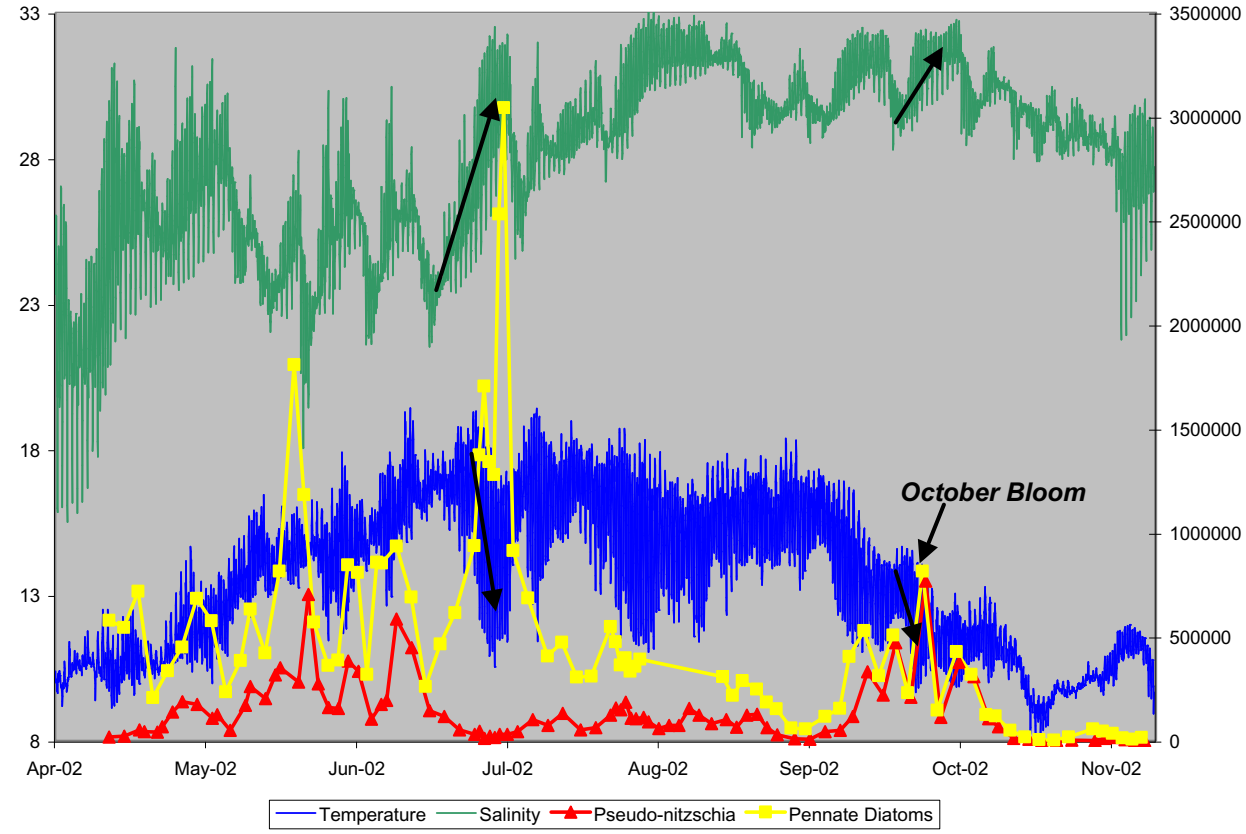

Figure 4. Pennate diatom (*Pseudo-nitzschia* spp.) blooms in summer and fall of 2002 as compared to temperature and salinity.

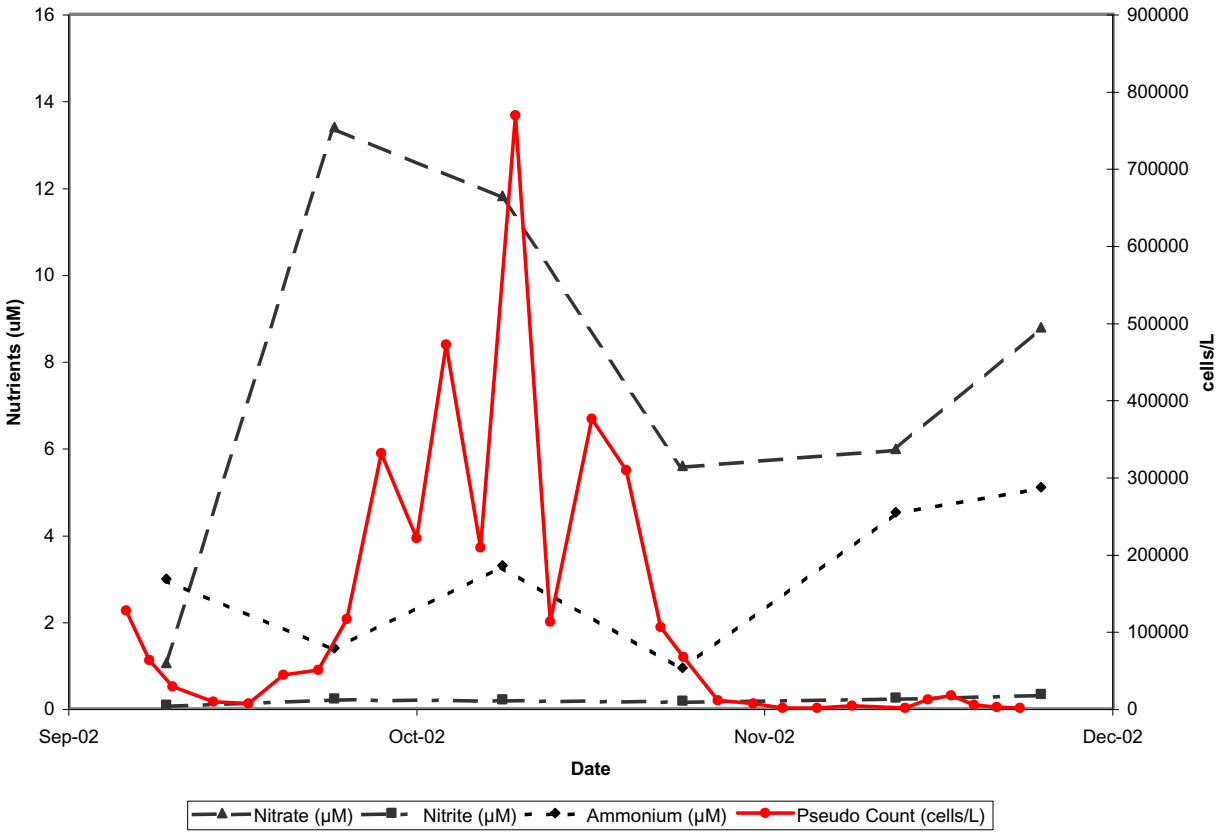

Figure 5. Nitrogen-containing nutrients at Bay Center, Willapa Bay from Sept. to Nov. 2002 with *Pseudo-nitzschia* overlay

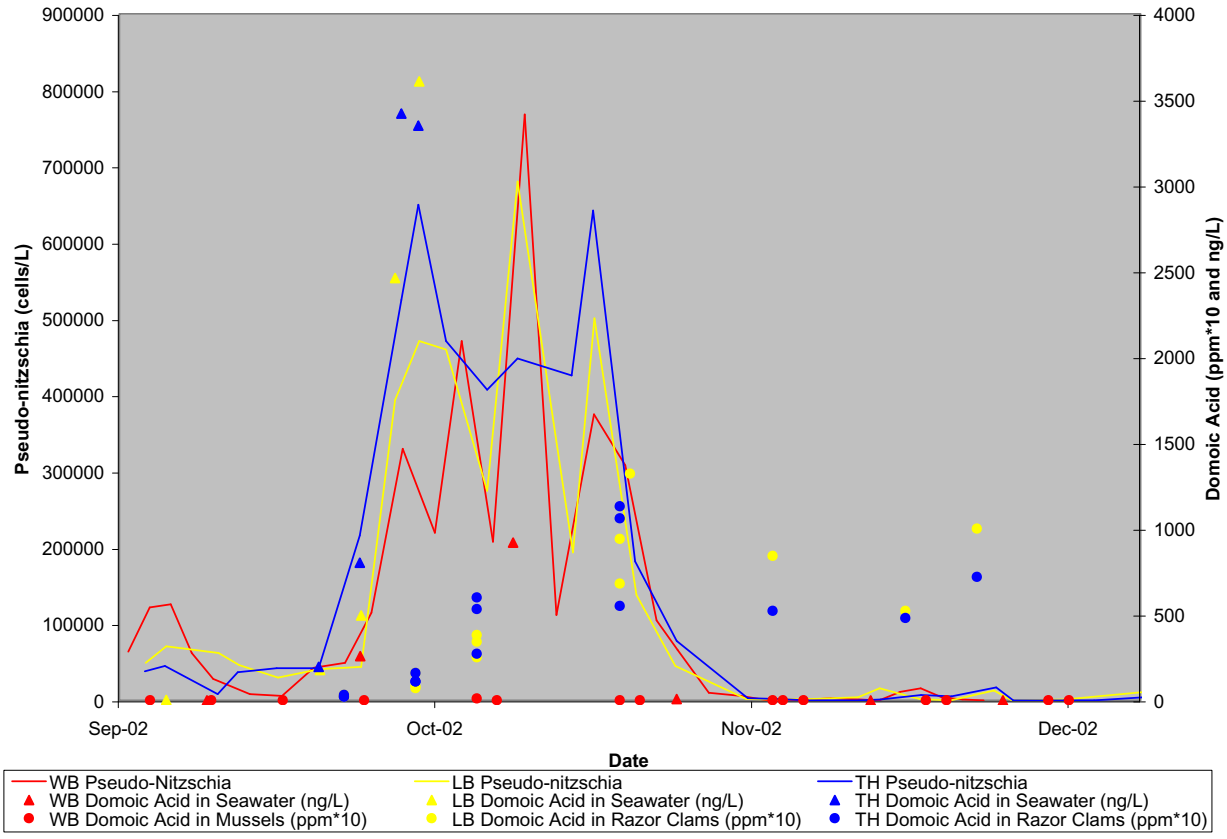

Figure 6. *Pseudo-nitzschia* and domoic acid levels in seawater and shellfish at Bay Center-Willapa Bay, Long Beach, and Twin Harbors.

Overall, the ability to see oceanic intrusions in Willapa Bay and track the effect of such intrusions is well defined. Estuarine data can be used to track offshore conditions for physical properties. The October bloom showed three indicators of oceanic intrusion: higher salinity, colder water temperatures, and elevated nitrate level. Therefore, we conclude that the *Pseudo-nitzschia* bloom in Willapa Bay was caused by an influx of ocean water into the bay. However, further investigation is needed to determine the specific processes that caused Willapa Bay shellfish to remain free of domoic acid or below the 20-ppm action level, when the water within the bay showed elevated levels of domoic acid caused by *Pseudo-nitzschia* spp. We need to establish whether this was a unique situation or common occurrence; a recent crab fishery closure occurred in Willapa Bay due to domoic acid, however it occurred beyond our monitoring season. Why the bay seems to remain less toxic, in general, when compared directly to nearby coastal monitoring sites is of concern as well. This question is important since Willapa Bay is a large estuary with many shellfish farms and the presence of domoic acid can pose a health threat to humans and other species that feed within the bay. Data will continue to be collected under the ORHAB grant, and provide additional data to answer these questions.

Literature cited

Newton, J.A. and R.A. Horner. 2003. Use of phytoplankton species indicators to track the origin of phytoplankton blooms in Willapa Bay, Washington. Estuaries, 26 (4B): 1072-1079.

Sayce, K. and R. A. Horner. 1996. *Pseudo-nitschia spp.* in Willapa Bay, Washington, 1992 and 1993, p. 131-136. In T. Yasumoto, Y. Oshima, and Y. Fu (eds.) Harmful and Toxic Algal Blooms. UNESCO, Paris.